INVESTIGATING A COMPUTERIZED SCAFFOLDING SOFTWARE FOR STUDENT DESIGNED SCIENCE INVESTIGATIONS

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University of Nebraska-Lincoln       December, 2008
Theoretical Background
Cognitive Processing of Stimuli

- Stimulus
- Sensory System
- Attention
- Working Memory
- Long-Term Memory

Stimulus activates relevant schema, affects processing, and activates relevant schema.
Cognitive Load

Total Working Memory Capacity

- Intrinsic Load: Inherent to the task
- Extraneous Load: Instructional design choices
- Germane Load: Due to “thinking”
Problems with Inquiry

Low level of chunking

- Little relevant schema for process
- Little relevant schema for content

Limits working memory capacity

- High intrinsic load
- No room for germane

Leads to

- Frustration
- Low levels of learning (content & process)
The Challenge

- Develop students’ skills to design investigations
- Provide scaffolding and effective instructional design to allow acquisition of content and procedural knowledge
Intervention #1

Backwards Design
Cognitive Load of Typical Lab Design Order

What do we need to use?

What are we going to do?

What data are we going to need?

What calculations or comparisons are needed?

What’s our overall goal?
Backwards design allows the pieces of information necessary for writing each step to already have been placed in external memory.

**Diagram:**
- Goal?
- Results?
- Data?
- Procedure?
- Materials?
Intervention #2

Reflective Prompts
Active Learning & Reflective Prompts

- Formation, adjustment, change in schema requires active processing of information
- Reflective prompts is one way to encourage active processing of information and procedures
Dissertation Study

Fall 2008
Research Questions

- How does the backwards-design scaffolding affect the quality of the student investigation reports?
- How do reflective prompts affect the quality of student investigation reports?
Research Hypotheses

- The quality of student-designed investigation reports will improve when students are provided with a backwards-design computer scaffold for student-designed labs.
- The quality of student-designed investigation reports will improve when students are provided with reflective prompts during student-designed labs.
### Study Design

<table>
<thead>
<tr>
<th>Backwards-Design Reflective Prompts</th>
<th>Student-Determined Design order Reflective prompts</th>
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IRB

- Parental consent forms
- Student assent forms
- All students perform task—those without signed consent and assent will complete task on paper
- Students graded on use of class time and effort
- Random login
- Login information stored in separate database as student lab reports
Task

- Determine which paper towel absorbs more per dollar.
- Completed the second week of school.
- Specific instructions and grading rubric for each section supplied within software.
- Students login with random usernames and passwords
  - Software presents them with their version
Data Collected

- Demographics
  - Grade-level
  - Previous high school science courses
  - Gender

- Lab Report
  - Graded with rubric
  - Individual lab report section grades
  - Overall lab report grade
Results and Discussion
Participants

- 19 began with group but finished later
- 83 complete task in 200 min
- 102 return IRB
The overall report score (all sections of the report) correlated with planning score (sections completed before performing experiment)

$r = 0.872 \ (p = 0.00)$

Overall score available for 83 students

Plan score available for 102 students

Plan score was used for analysis
Score Validation

- Random sample of 20 student reports scored independently by another chemistry teacher using the same rubric.
  - Scores correlated
    - $r = 0.872$ ($p = 0.000$)
Variances

- Bartlett’s test of variance
  - non-significant finding, $p = 0.997$
- Variances of all treatment groups not significantly different
Summary of Plan Scores

Maximum 30 points

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<tr>
<th>Student Planning Scores</th>
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<tr>
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<td>M = 22.45</td>
<td>M = 20.48</td>
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<td>Scaffolding</td>
<td>s = 4.056</td>
<td>s = 4.128</td>
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<tr>
<td></td>
<td>n = 22</td>
<td>n = 29</td>
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<td>Student-Determined</td>
<td>M = 19.09</td>
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<tr>
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<td>s = 4.133</td>
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- Significant interaction
  - $F(1,98) = 4.127$
  - $p = 0.045$
## Significant Main Effect

Maximum 30 points

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- **Significant effect only when no reflective prompts**
  - $F(1,43) = 7.26$
  - $p = 0.010$
  - Cohen’s $d$ effect size of $0.82$

- **No other effects found**
Reflective Prompts

- When reflective prompts used, effect of backwards scaffolding disappeared

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Reflective Prompt Use

- Reflective prompt use was inconsistent

- Backwards scaffolding reflected 3 times versus 1 time for students not scaffolded in design order
Too much time interacting with supports (including reflection) reduces time for adequate model formation (Manlove et al., 2006)

Regulatory processes (monitoring, reflecting, et al.) require working memory (Winne, 1995)

This effect is more profound for lower level students (Manlove et al., Winne)

Help systems need to match learner-related factors (Aleven et al., 2003)
Disaggregating Data

- Is the use of 3 reflective prompts negating the positive effect of backwards-scaffolding?

- Measure of overall student achievement
  - The course taken their freshman year:
    - Biology or Empirical Science = Advanced students
    - Physical Science = Regular students
## Advanced Student Data

Maximum 30 points

### Plan Scores for Advanced Students

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<td>M = 24.18</td>
<td>M = 23.71</td>
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<tr>
<td></td>
<td>s = 2.04</td>
<td>s = 3.039</td>
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<tr>
<td></td>
<td>n = 11</td>
<td>n = 7</td>
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<td></td>
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<td>Student-Determined</td>
<td>M = 19.23</td>
<td>M = 20.92</td>
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<tr>
<td></td>
<td>s = 4.456</td>
<td>s = 4.582</td>
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<td>n = 13</td>
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[□] Interaction effect has disappeared
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- **Main Effect for backwards scaffolding**
- $\text{F}(1,39) = 10.494$
- $p = 0.002$
- $d = 1.5$
## Summary of Findings

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<td><strong>All students</strong></td>
<td>Significant effect.</td>
<td>Significant effect, positive large effect size (p = 0.010, d = 0.82) for no-reflective prompts only.</td>
<td>No significant effect.</td>
</tr>
<tr>
<td><strong>Advanced students</strong></td>
<td>No significant effect.</td>
<td>Significant positive large effect (p = 0.002, d = 1.5).</td>
<td>No effect.</td>
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Making Sense of Findings

- Large main effect for backwards for advanced students
- No effect for reflective prompt for advanced students
- Diminished effect of backwards when reflective prompts used with all students
- Literature reporting working memory demand of regulation for lower level students
- Lower level students needed different level of regulation scaffolding to not interfere with task
In other words...

Higher level students were OK with the demands of the reflective prompts.

Reflective prompts (especially multiple times) presented to high a cognitive demand for lower level students.

Backwards design scaffolding improves student performance when other scaffolds are at an appropriate level for the student.
Limitations

- Students knew grade did not depend on lab score
- Difficult to maintain individual nature of task once students began performing the lab in the classroom
- Smaller sample sizes for disaggregated data
- Plan to measure cognitive load with effort and difficulty questions abandoned
  - Students were frustrated with computers we were assigned and working individually
  - These factors affected their difficulty ratings more than the task itself
Recommendations

- Progress meter to let students know their progress
  - Already in place
- Adapt self-regulation and monitoring demands to student level
- Allow for students to choose how they want to proceed
  - with or without design-order scaffolding
  - based on their comfort level with the task
  - decision can be changed during the task
Future Plans

- NSF grant proposal
- Investigate fading of scaffolding
  - Appropriate ways to scaffold
  - Programming to automatically scaffold based on students’ previous scores and experiences and reinstate scaffolding if students performance drops
- Create “tracking” software for use as school, district or state performance assessment tracker
- Development of age-group appropriate tasks and rubrics for use in the “tracker” software